HISTORY

OF THE

HARVARD COLLEGE OBSERVATORY

DURING THE PERIOD 1840–1890.

BY

DANIEL W. BAKER.

Reprinted from the Boston Evening Traveller.

CAMBRIDGE.

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PREFACE.

A careful study of the early history of the Harvard College Observatory has been made by Mr. Daniel W. Baker. Many facts were thus brought to light which had not appeared in print. A series of newspaper articles was accordingly prepared, which were published in the Boston "Evening Traveller" on six successive Saturdays, beginning August 2, 1890. Much of this material appearing to be of sufficient value for preservation in a more permanent form, it has been reprinted in the present pamphlet, with slight alterations, and with the addition of the illustrations given on page 25. The parts numbered IV. and V. originally appeared together as a single article. Reproductions have been made of some of the illustrations. The articles were originally addressed, not to professional astronomers, but to the general public, and are to be regarded as a popular description of the work accomplished at the Harvard College Observatory during the first fifty years of its existence.

EDWARD C. PICKERING.

Harvard College Observatory,
September 13, 1890.

HISTORY

OF

THE HARVARD COLLEGE OBSERVATORY.

1840-1890.

The present is the semi-centennial year of the Harvard College Observatory. A precise date cannot be named for the beginning, but in the early months of the year 1840 the institution was gradually organized, and before midsummer became a tangible fact and a working adjunct of the college.

While the first astronomical observation is of record Dec. 31, 1839, it is well known that the observatory had not then an official staff, the appointment of the first director being of date Feb. 12, 1840, and the confirmation by the Board of Overseers somewhat later. Moreover, this particular observation and others immediately following were made in continuation of work begun elsewhere and not identified with the college affairs.

The advance made in astronomical science during the 50 years past is among the wonderful facts comprised in the record of the 19th century, and it is true that since it became fairly organized and equipped, Harvard College Observatory has been in the front rank in the march. A review of this progress so far as pertaining to the institution at Cambridge, is, therefore, timely. A history of 50 years, embodying so many facts of the first importance and interest as does this, cannot, even with the most resolute purpose as respects brevity, be disposed of in a single chapter. This, accordingly, will be the first of a series. The reader may be assured at the outset that the topics to be touched upon are various and in themselves attractive, and that, so far as possible, technicalities will be shunned.

Regarding the period of beginning just referred to as the blossoming, whence has followed abundant fruitage, it may be remarked that a long time passed between the budding and the blossoming, and that indications of the flow of a vital current are recognizable at as remote a date as 1761. In that year the sloop owned by the province of Massachusetts was fitted out at public cost to convey Prof. John Winthrop and others connected with the college, provided with instruments belonging to the college, to Newfoundland, for observation of a transit of Venus. In 1780, notwithstanding the financial straits incident to the war, the commonwealth provided a small vessel of war, called a "galley," to take Prof. Samuel Williams, of the college, and party to Penobscot to observe a total eclipse of the sun. The first definite record pointing to a college observatory is of date 1805, when John Lowell, the uncle of that John Lowell who founded the Lowell Institute, being in Paris, consulted with Delambre, an astronomer of note, and procured from him written instructions as to suitable buildings and instruments for an observatory. This document was sent to the college authorities at Cambridge. No official action followed. The next of record is that the college authorities in 1815 appointed a committee to consider and report upon an eligible plan for an observatory. This is supposed to have been the first corporate action taken in the United States, having such an object in view. The doings of this committee are notable in two particulars, at least. They brought into official relations with the college for the first time, the man who was destined to be the builder and organizer of the observatory, 25 years later, William Cranch Bond.

He was about to visit Europe and was appointed the agent of the college to obtain information as to the construction and instrumental equipment of the observatory at Greenwich, and to make such plans, drawings, etc., as would enable him or another to construct an astronomical observatory at Cambridge;

also to ascertain from the makers the cost of certain principal instruments like those at Greenwich. He performed the service and reported in detail in the following year. That nothing practical came of it for a quarter of a century was not owing to the will, but comparatively speaking, to the poverty of the college.

This result followed, however,—and it may be reckoned the second notable circumstance—that, upon his return, Mr. Bond constructed the model of an astronomical dome, the operative plan of which was the same as that of the great dome, built in 1844, and which has been in satisfactory use at Cambridge to the present time. The chief peculiarity of its mechanism is in the method of rotation by means of smoothly-turned spheres of iron. The dome rests on these at equi-distant points, and, being set in motion by suitable gearing, the iron balls sustaining its weight roll along a level circular track of iron, the circumference of which is equal to that of the dome. The method was unlike that previously in use. It appears to have been original with Mr. Bond, as is perhaps evinced by a remark in his report for 1848 referring to the matter: "If carefully examined, it will be found that this arrangement is as perfect in theory as it is appropriate and convenient in practice." Experience has shown that spheres of hard bronze are more serviceable than those of iron, and bronze is now used.

The record indicates that an observatory did not cease to be a coveted object at any time during the 25 years prior to 1840. Two antecedent events, in themselves of importance, combined to bring the long cherished project to a happy issue,—the accession of Josiah Quincy to the presidency of the college and the action of Congress in authorizing what came to be popularly known as the "Wilkes Exploring Expedition." The purpose of the expedition in part was to establish the latitudes and longitudes of uncharted places in distant parts of the world where American commerce was extending, and in part to investigate natural phenomena, including the facts of terrestrial magnetism. Having, after much delay, got an adequate appropriation, the naval department employed the best available talent of the country for the conduct of the enterprise.

Mr. Bond was engaged to make at his private observatory in Dorchester, Mass., investigations to fix a zero of longitude, whence final reference to Greenwich might be had, and to make a continuous record of magnetic observations at Dorchester for comparison with like records obtained at distant points by the expedition itself. As preliminary to the latter work, Mr. Bond tested in an isolated observatory in Dorchester the magnetic instruments with which the expedition was to be equipped.

Mr. Bond's talents were as well known at Cambridge as at Washington. What

THE DANA HOUSE.

Mr. Quincy did in the premises can best be stated in his own words: "Early in the year 1839, the exploring expedition then being in the Southern ocean, it occurred to the president of the university that if Mr. Bond could be induced to transfer his residence and apparatus to Cambridge and pursue his observations there, under the auspices of the university, it would have an important influence in clearing the way for an establishment of an efficient observatory in connection with that seminary, by the increase of the apparatus at its command, by the interest which the observations making by Mr. Bond were calculated to excite, and, by drawing the attention of the citizens of Boston and its vicinity to the great inadequacy of the means possessed by the university for efficient astronomical observations, create a desire and a disposition to supply them."

This proposition, Mr. Quincy says in another connection, he made without having consulted with the corporation. That body sanctioned his action by making a formal contract with Mr. Bond, of date Nov. 30, 1839, the agreement on Mr. Bond's part being to make the transfer as proposed. Steps were at once taken by the college authorities to secure a subscription of $100 each from 30 different gentlemen, which sum was applied, under Mr. Bond's direction, in alterations and additions to a dwelling house owned by the college and known as the "Dana house." It still stands upon its original site at the junction of Quincy and Harvard streets, the lot being the southeast corner of what are distinctively called "the college grounds."

The cupola which crowns the roof is a reminder and proof of a part of these alterations; for within it was set up one of the telescopes of the first college observatory, the cupola when constructed being suitably domed for the purpose. Something practical in astronomy had always been taught in the college course. In this way, or possibly by Mr. Bond himself, the position of Harvard Hall on the college grounds had been determined. Thus, in a paper published by him in 1833 in the Memoirs of the American Academy, he gives the position of his observatory in Dorchester as "0°-3′-15″ east of Harvard Hall in Cambridge."

That the astronomical equipment possessed by the college before Mr. Bond's coming did not amount to the beginning of a proper observatory, sufficiently appears by a contemporary letter of Prof. Joseph Lovering, written in response to an official inquiry. He says that the college had at the time "no instrument of much value for determining either time or position, and no place more convenient for using instruments than an open field, or a window which might accidentally open in the right direction." He gives the inventory, comprising an astronomical clock, which, he says, cannot be relied on for accurate time; a small transit instrument, which at one time was loaned to Dr. Bowditch, but returned, he having found it of little value; two reflecting telescopes of three feet and two feet focal length; and a refractor of three feet focal, which three, he says, "answered decently well for showing the moon, Jupiter's satellites, Saturn's ring, etc., to the students, but were very imperfect for any nice observation." These, with an astronomical quadrant and a common quadrant, complete the list. The list of instruments brought by Mr. Bond does not appear in the printed records, but in the paper above referred to he names his instruments used at Dorchester as a Gregorian reflector of 30 inches focus, equatorially mounted, an achromatic telescope of 40 inches focus, a Borda's circle, a Ramsden's sextant, and two transit clocks. The clocks he describes as "excellent," and says that they had mercurial pendulums.

In the early observations of Mr. Bond at Cambridge, priority was given to the work begun at Dorchester for the naval department. In the college record a considerable part of the routine is classed as meteorology, with reference, chiefly, to the earth's magnetism. The scheme of observation in this department was, however, much broadened, and in this the observatory appears to have performed its first notable service to pure science and to have assumed a place that gave it international recognition. For these observations the best known apparatus was procured and put into service in a building on the college grounds set at a distance from the Dana house, but connected therewith by a covered way. It was known as the "Lloyd apparatus." It consisted chiefly of three magnetometers, one for indicating declination, one for horizontal force and the third for vertical force.

It was the product of the same firm in

England which had made like instruments for the British government for use at meteorological stations at Greenwich, Eng., Toronto, Can., St. Helena, Cape of Good Hope, Bombay, Madras, Singapore and Van Diemen's Land. The magnetic observations at Cambridge were conducted according to the same formula as that in use at these British stations, with a purpose of co-operation. In this cosmical investigation the German Meteorological Association, having many observatories under its direction, and the Russian government, having magnetic stations at various points between the borders of China and the Arctic Circle, joined. This Lloyd apparatus was the observatory. Soon afterwards the present observatory grounds, then known as "Summer House hill," were bought.

Up to this time astronomical work had been carried on at the Dana house to the extent possible with the few instruments of precision at command, much of it by Mr. W. C. Bond, Jr., whose decease, in 1842, was regarded a loss to science. The contract of the senior Mr. Bond with the United States government ended in 1842, and in July of that year a movement was made having in view the purchase of a first-class telescope, but it was a matter of inquiry as to cost, etc., only. Under ordinary circumstances what was thus sought for, a proper observatory build-

MAIN OBSERVATORY BUILDING, SHOWING THE DIRECTOR'S RESIDENCE AND THE GREAT DOME.

gift of the American Academy of Arts and Sciences, by vote of April 22, 1840, and was of the value of $1000.

Many interesting particulars of the early days of Harvard College observatory are given in the first volume of printed annals of the institution. In the reading an essential fact is to be kept in mind, the difference of the pecuniary standards of that and the present time. The writer of an official document of 1843, was, in view of that difference, neither inexact nor ironical when he characterized a conditional offer of $5000 for the observatory, made that year by Hon. David Sears, as "a munificent proposal." It was soon found that the Dana-house site would serve only temporarily, and on Sept. 4, 1841, action was taken for the building of a permanent

ing and a telescope equal to the more difficult problems of astronomy, would have been slowly arrived at.

But early in March, 1843, the great comet of that year suddenly appeared in the evening sky, near to the sun. It was an astonishing phenomenon, and wrought the popular as well as the scientific mind into a state of excitement.

The comet had passed perihelion on Feb. 27, and was seen at one place in New England on the 28th, close to the sun. During its brightest period it was visible in the daytime at one place in this section of the country from 7.30 A.M. to 3 P.M., when clouds intervened; and in Mexico from 9 A.M. till sunset. It passed but about 90,000 miles from the sun's surface and through more than 300,000 miles of the sun's corona, its velocity then be-

ing 350 miles per second. Its head was small, but its tail large and brilliant. The total light emitted by the meteor is stated by Prof. Loomis to have been equal to that of the moon at midnight in a clear sky. By the telescope its tail could be traced over a computed distance of 108,000,000 miles, so that had it been pointed towards the earth it would have passed through the planet's atmosphere and 15,000,000 miles beyond.

The professor names as its notable characteristics "its small perihelion distance, nearly as small as is physically possible, and its prodigious length of tail." It continued visible into the following month. It is known in the books as "the great comet of 1843," but for reasons which will appear, it might well be called "the Harvard comet." The friends of the young institution at Cambridge perceived that the moment was opportune for an appeal to the moneyed public. The prevalent curiosity as to the visitor could not be gratified by the observers at the Dana house.

They had no instruments fit for the occasion. An altitude-and-azimuth instrument, which had been used in the state survey of 1831, was borrowed and mounted in the cupola, and thus, on March 9, an observation was first made; but nothing came of the endeavor, it being found impossible to secure permanent adjustments. The next thing done was to call a meeting of citizens in Boston. The chairman was Hon. Abbot Lawrence. Addresses were made by Hon. John Pickering, Prof. Benjamin Peirce, Hon. William Appleton and Hon. S. A. Eliot. A financial committee was appointed, and subscriptions to the amount of $25,000 were obtained in Boston, Salem, New Bedford and Nantucket.

Thus encouraged, the official board of the college negotiated for the purchase of the best telescope that could be produced in Europe, a refractor of 15 inches aperture, equatorially mounted, the makers being Merz & Mahler of Munich. The spot for building a massive stone supporting pier on Summer-house hill was fixed Aug. 12, 1843, and ground was broken for the work on Aug. 15.

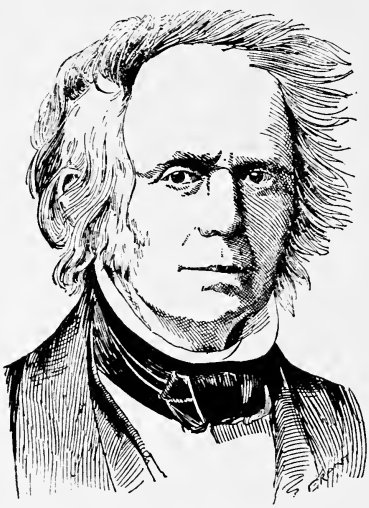
These were the experiences which Prof. Benjamin Peirce had in mind when in later years he spoke in eulogy of Prof. Bond, then deceased, in phrase which is both of historical and biographical interest. Having mentioned some of the early difficulties, he said: "When, in 1839, Mr. Bond was drawn to Cambridge by the strong hand of President Quincy, when the cause of the observatory was undertaken by the unflinching and irresistible vigor of our friend J. Ingersoll Bowditch, when even the heavens came to our assistance, and that wonderful comet of 1843 excited most opportunely a universal interest in celestial phenomena,—it was then apparent that the affection for Mr. Bond was the chief strength of the occasion, and to that we were mainly indebted for the successful attempt to obtain the unrivalled equatorial and to lay the foundations of the observatory." No proper biography of Mr. Bond, whose career was an honor to his country, has ever been published. A sketch, the facts for which have largely been derived from original sources, may fittingly be given as the next number in this series.

II.

A casual glance at the circumstances of the beginning of the famous observatory in the neighboring city of Cambridge will show that a most important contribution to the success of that enterprise was made by the first director of the observatory, Prof. W. C. Bond. The more diligently those circumstances are studied, the stronger will be the conviction that his work, while it was that of designer and organizer, was also somewhat better in the sense of being more rare in quality; that his presence and enthusiasm gave the institution vitality. The record of his life gives him title to rank among eminent Americans.

William Cranch Bond was born in Portland, Me., Sept. 9, 1789. He was the youngest son of William and Hannah (Cranch) Bond, who were natives of England. The family was of distinction there, and is genealogically traceable to the time of William the Conqueror, or earlier. The Brandon manor is said to have been granted by that monarch to the ancestor of this line, and to have been held by the family through many generations. William Bond was born in Plymouth, Eng. Richard Cranch, an uncle of Hannah, settled in Braintree, Mass., in 1751. The name, in himself and his descendants, became distinguished in the annals of the province and commonwealth. From him William Bond received information which induced him

to emigrate to this country. He located for business purposes at Portland, then Falmouth, and engaged in cutting ship-timber at Frenchman's bay, sending the commodity to England. He made a voyage thence to England, returning with his wife and elder children. The timber business proved in the end unprofitable and he removed to Boston in 1793, where he established himself in his vocation of clockmaker and silversmith, his stand being at the corner of Milk and Marlboro, now Washington street. The youth of William C. Bond was, accordingly, spent in Boston, where he had such education as the common schools afforded. Indeed,



PROF. W. C. BOND.

that he did not have fully that privilege, may be inferred from his remark quoted by Josiah Quincy, that pecuniary restrictions "obliged me to become an apprentice to my father before I had learned the multiplication table." Mainly he was self-taught, though doubtless he derived instruction from his father, who was a well-informed man, and from some of the Cranch relatives, who were of good education. The traditions of the family and the facts of his career, indicate his mental quality to have been that of genius, one trait of which is that it absorbs congenial knowledge from unpromising materials and amidst adverse conditions.

His eldest sister wrote of him as having been, at the age of 14, "a slender boy with soft gray eyes and silky, brown hair, quick to observe, yet shrinking from notice, and sensitive to excess." She adds, in reference to his early-developed tastes: "The first that I remember, was his intense anxiety about the expected total eclipse of the sun of June 16, 1806. He had then no instrument of his own, but watched the event from a house-top on Summer street through a telescope belonging to Mr. Francis Gray, to which, somehow, he got access. In so doing he injured his eyes and for a long time was troubled in his vision." An elder brother writes of him at this early period: "He was the mildest and best-tempered boy I ever knew, and his remarkable mechanical genius showed itself very early." He adds that in devising and making bits of apparatus that boys use in their sports, William was chief among his comrades. His early apprenticeship in the clock-making business undoubtedly gave a fortunate discipline to this natural ingenuity, by confining his experiments pretty closely to the facilities of his father's workshop as to tools and materials.

He found or made "idle time" enough before he was 15 years old to construct a reliable shop-chronometer. It had to be a fixture, for lacking a suitable spring he contrived to run it by weights.

When he was about 16 years of age he made a good working quadrant out of ebony and boxwood, the only materials he had. His son, G. P. Bond, wrote of this instrument, years afterwards: "It is no rude affair, but every part, especially the graduation, the most difficult of all, shows the neatness, patience, and accuracy of a practised artist. A better witness to the progress he had already made in astronomy could not be desired. It is all that the materials would admit of, and proves that he must have been, even then, irrevocably devoted to astronomy."

How these "eccentricities of genius" were looked upon by the senior Mr. Bond does not appear, but, at any rate, William was made a member of the firm about the date of his majority, and forthwith the clockmaking business was expanded to include the rating, repairing and making of chronometers. Astronomy could now go hand in hand with "business." He must have had the means of ascertaining the true local time before he was himself owner of an in

strument suited to that purpose. He made his first seagoing chronometer in 1812, and it was the first made in America. Its engraved trade mark was "Wm. C. Bond, 1812." It at once went into service, and satisfactorily stood the test of a voyage to and from the East Indies. For making this he had a working model; the stationary or shop chronometer of 1804 was made according to a description he found in an old French book of a chronometer used by La Perouse, the navigator. In 1810 the business of the Bonds was removed to Congress street. About the same time the family removed to Dorchester where for a while they occupied, as tenants, different houses.

Mr. Bond himself said in his later years that what first gave him a determination for astronomy was his experience of the total eclipse of 1806. Once aroused, the feeling never ceased to have sway, and it modified all his business ambitions as a chronometer maker. But as such an artisan he had excuse in the eyes of the practical minded for his loved explorations into the starry depths. In the lack of proper instruments his earliest observations were made by crude methods, which yet gave proof of his originality and of the fascination which the study had for him. It was soon after 1811 that he first gained recognition from any one competent to pass judgment upon his essential mental qualities. On Sept. 4, 1811, Prof. John Farrar of Harvard College first caught sight of a comet in the western sky. He appears to have at once notified Dr. Nathaniel Bowditch of Salem, and they two, and a few others in New England who had telescopes, traced its subsequent progress. Each of the two published an account of his observations in the Memoirs of the American Academy. Prof. Farrar having given in his introductory paragraph the date of his first observation, adds that the comet had been seen earlier by Mr. Bond of Dorchester, whom he calls "William Bond, Jr.," and says that Mr. Bond had "obligingly favored" him with the following notices:

I remarked on the 21st of April a faint, whitish light near the constellation Canis Major, projecting a tail about one degree in length, and set down its place as follows: Right ascension, 106°; declination, 9° S. April 24, right ascension, 108°; declination, 7° or 8° S. Its motion and the situation of its tail convinced me that it was a comet. I noticed it several times in May, and supposed that its motion was toward the western part of the constellation Leo.

By messages coming in sailing ships it was learned subsequently to September that the comet had been seen in Europe on March 25. Its perihelion passage was September 12, 1811.

The elder brother already quoted says of these early days: "I suppose it would cause the astronomer royal to laugh could he see the first transit instrument used by us at Dorchester, a strip of brass nailed to the east end of the house, with a hole in it to see a fixed star and note its transit; this in 1813. When we moved into the Hawes house, he procured a good granite block; we dug a deep hole and placed it at the west end of the house and got Mr. Alger to cast a stand for the transit instrument, a small one, which I think belonged to Harvard College. From this time he began to live among the stars."

The facts thus recorded of the beginning of Mr. Bond's career show his zeal and watchfulness as an amateur in astronomy, and that up to the date of the comet's appearance, and later, he had no personal acquaintance with men of science in the vicinity, since he informed none of them of what he had seen. When, months afterwards, Prof. Farrar inquired about it, the young discoverer was able to report from his memoranda no more than the degrees of position, without the minutes and seconds, and to say that he "supposed" the comet to be moving towards the constellation Leo, circumstances indicating that a strip of brass with a hole in it and a home-made boxwood quadrant were all that was astronomically in use at Dorchester as late as 1811.

That this experience with the comet was a fortunate turning point in Mr. Bond's career is evinced by Prof. Farrar's genial recognition in the paper published in the organ of American Science, where he might excusably have ignored so crude a record as that which was the best Mr. Bond could supply, and by the appearance not long afterwards, at the west end of the Hawes house in Dorchester, of a loaned telescope belonging to Harvard College.

There is no doubt that whatever previously had been lacking of opportunity to gain knowledge of the technics of astronomical science was now fully

within his reach and that henceforth he he had the best possible of instructors and counsellors so far as he had occasion for any. Mr. George P. Bond writes of his father: "He has mentioned the names of Dr. Nathaniel Bowditch, Prof. Farrar and Tutor Clapp as those from whom he received most encouragement to continue the cultivation of astronomy. Upon his friendly intercourse with the eminent mathematician and astronomer first named he often dwelt with peculiar pleasure and warmth of feeling." The name of one other of the godfathers of the young scientist is entitled to be mentioned, that of Josiah Quincy. The lady above quoted gives an account of the setting up of the first telescope at Dorchester by her brother, and says that through it could be seen the satellites of Jupiter and the rings of Saturn. She adds that in the pursuit of astronomy up to this period "he had had no assistance whatever except from the genial kindness of Hon. Josiah Quincy, who had early recognized the future astronomer in the unpretending boy in the watchmaker's shop on Congress street, and whose kindness and encouragement never failed throughout the subsequent years."

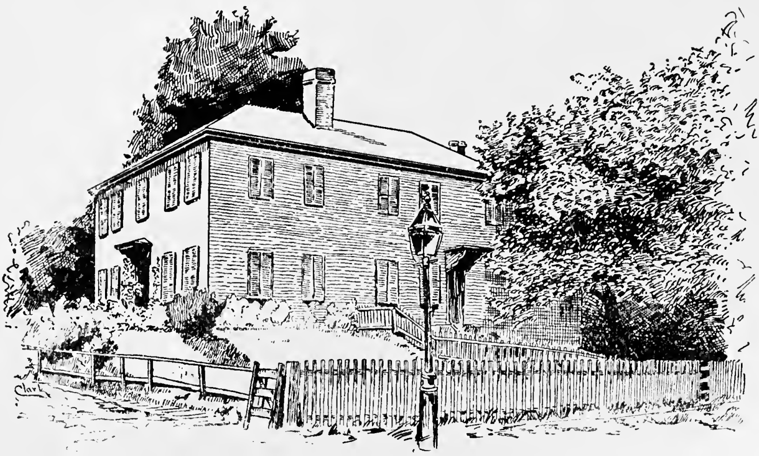
That these men found their patronage to have been well bestowed is manifest from the action taken four years after the date of the comet by the college in making Mr. Bond its delegate and agent. The board of that year consisted of President Kirkland, John Lathrop, D.D., Christopher Gore, LL.D., John Davis, LL.D., John Lowell, LL.D., and John Phillips. It is of record that the moving spirits in the matter were Prof. Farrar and Dr. Bowditch, and they were appointed a committee to prepare technical written instructions to the agent as to the general scope of his inquiry.

During his visit abroad, Mr. Bond married his cousin, Selina Cranch, of Kingsbridge, in Devonshire, the date being July 18, 1819. Soon after his return he purchased a house near to his father's residence in Dorchester, and erected on the premises a small wooden building, which he carefully equipped as an astronomical observatory. Its position is that meant in the official references to the observatory at Dorchester, and is about 45 feet southerly of the present south line of Cottage street, and 360 feet southeasterly of the centre of the New York & New England railroad bridge, over that street. Here, as one of his brief biographers remarks, "no eclipse or occultation escaped him, though occupied in business during the day in Boston," and here Mr. Quincy found him in 1839, busy in his work for the Navy Department. The period which had elapsed since the setting of the granite block and the poising upon it of the borrowed telescope had been for Mr. Bond one of constant and rapid advance in the astronomer's art. The Cottage-street observatory was built about the year 1823.

Referring to the period between 1823, or a little earlier, and 1839, Mr. G. P. Bond writes of his father: "As soon as his circumstances permitted, he imported more perfect apparatus from Europe and continued to add to his collection until it was the best in the country." And he adds this statement, which is highly suggestive as respects the enthusiasm with which the accomplished and successful chronometer maker entered upon the broader and loftier mission which destiny had in reserve for him: "When appointed by the Navy Department to the charge of astronomical and other observations, he forthwith laid out a sum of money on instruments and buildings more than ten times greater than the annual salary (to continue but four years), which he had himself proposed as an adequate compensation for all necessary expenses, and his own time, besides."

During a few years prior to 1830, he gathered materials for investigating the comparative rates of chronometers at sea and on shore. Subsequently he communicated to the American Academy the results reached, and in this paper effectually disposed of the scientific question involved, so far as it related to the interests of navigation. The authority for this statement is Mr. G. P. Bond, who also says that about the same time his father conducted a series of experiments to ascertain the influence of changes of temperature in the presence of large surfaces of iron upon the performance of chronometers; and adds that "although the conclusions arrived at were at variance with the opinions of men high in authority in such matters, they are now known to be correct."

President Quincy, in making his overture, was dealing with no novice, and, certainly, no stranger. Some intimation of what Mr. Bond had attained to is contained in the remarks of Prof. Benjamin Peirce spoken in the obituary proceed-



THE BOND HOUSE, DORCHESTER.

View looking to the southwest. The Observatory stood contiguous to the west end.

ings of the American Academy in 1859, consequent upon Mr. Bond's decease, though the reference is to a longer period. The instrument alluded to is the great equatorial at Cambridge. Prof. Peirce said: "In his original investigations he naturally restrained himself to those forms of observation which were fully within the reach of his own resources. He did not, therefore, seek those inquiries which could only be accomplished by long, intricate, and profound mathematical computations, but preferred those which were purely dependent upon the thorough discipline of the senses. He consequently availed himself less of the remarkable capacity of his instrument for delicate and refined measurements than of its exquisite optical qualities. But when observations were required which must be passed over to the computer, his skill was not wanting to the occasion. Thus, in conjunction with Major Graham, he made that choice series of observations from which the latitude of the observatory was determined."

To this testimony as to Prof. Bond's skill as an observer may be added that of Mr. G. P. Bond as to his diligence and zeal: "There is something to my mind appalling in the contemplation of my father's labors, from the time when he was first enabled to indulge freely his passion for observation. The accumulated volumes filled with manuscript records give me a shudder at the thought of the weary frame and straining eye, the exposure, and the long, sleepless nights that they suggest."

Ex-President Quincy, upon the obituary occasion referred to, made this interesting statement as to the initiation of his project for Mr. Bond's removal to Cambridge: "This proposal, so in unison with his pursuits and talents, I expected would be received with pleasure. But it was far otherwise. In the spirit of that innate modesty which predominated in his character, and apparently cast a shadow over all his excellent qualities and attainments, Mr. Bond hesitated, doubted his qualifications for the position. He said his habits were not adapted to public station; that our combined apparatus would be small, and that something great might be expected; that he preferred independence in obscurity to responsibility in an elevated position. He raised many other objections, which need not here be repeated, as they were overcome."

At the date of this interview the president found Mr. Bond well established in a profitable manufacturing business, happily situated in his domestic and neighborhood surroundings, with an avocation fascinating enough to occupy all his leisure and a fame extensive enough to satisfy his own modest estimate of his abilities. There was no pecuniary betterment for Mr. Bond in the suggested change. Mr. Quincy could only offer him

what he had already, a family domicile; so that the proposal might warrant an adaptation of Sidney Smith's famous phrase and be described as an invitation to come to Cambridge and "cultivate astronomy upon a little oatmeal." In so phrasing it there is no disparagement of the college; it was the day of small things, of pennies, not dollars, in the college treasury. But the event speaks the praises of Mr. Quincy, whose sagacity was unfailing and before whose persuasiveness and energy difficulties in administration were wont to give way, and of Mr. Bond, whose unselfishness and loyalty to science were proof against pecuniary considerations. In mental traits each was in many respects the complement of the other, and it is not too much to say that these two were pre-eminently the founders and builders of the observatory.

The official report for 1846 states that up to that time the labors of Mr. Bond had been "entirely unrequited, except by the gratification of his love of science and of home," and suggests that this devotion to the institution at Cambridge was the more marked in that during the preceding spring he had declined "the almost unlimited offers made to him by the administration at Washington to induce him to take charge of the observatory there." It is known, also, that frequent expenditures of his own money were made during this period for current expenses and for things convenient in conducting the observatory, sums small severally, no doubt, but considerable in the total. In 1846 a sum equal to the proposed salaries for the next two years was subscribed by citizens of Boston, and in 1849 the official board was able to report that "through a bequest of $100,000 made by Edward Bromfield Phillips they should thereafter be relieved from anxiety as to the payment of salaries and current expenses." Various official documents evince that during the first eight years Mr. Bond is to be regarded not in the character of an employee, but a benefactor of the college; that his labors were deemed by those most familiar with them to be indispensable and invaluable, and that his friendship for the college, manifested in all ways, and especially in his declination of the liberal offers coming from Washington, was appreciated and honored. The date of Mr. Bond's appointment as director of the observatory was Feb. 12, 1840, though the confirmation by the corporation was later. He was given the honorary degree of A.M., by Harvard in 1842.

III.

In resuming consecutively the story of the half-century's progress of Harvard College Observatory, which was interrupted in the preceding number to give place to a biographical notice of Prof. W. C. Bond, it may be remarked that the period of his official term, which covered 19 years, was fruitful in great discoveries and events in the astronomical department of science. Harvard Observatory contributed its full share, though the greatest of all was that which gave fame to Le Verrier, the French astronomer, the discovery of the planet Neptune. In September, 1844, the observatory building on Summer House hill had been completed to the extent proposed at that time, and the instruments were transferred from the Dana house.

A new transit instrument, imported by the United States government for the use of the Northeastern Boundary Commission, was set up in December, and used during the winter in observations for ascertaining the latitude, as previously described in the quotation from Prof. Peirce. The results were collated and discussed by Prof. Peirce in the memoirs of the American Academy. These were the first notable observations of precision at the new observatory. The longitude was also determined by the most accurate method then known, observation of occultations and moon culminations and comparison of a considerable number of chronometers transported to and from Greenwich by ocean steamers. In the ultimate determination the record made by several hundred chronometers thus sent to and fro, and observations of occultations, etc., in Dorchester, Cambridge, Brooklyn, Philadelphia and Washington, ranging through many years, were brought into the account. The earliest were observations made in Philadelphia in 1769. After the laying of the Atlantic cable still closer comparisons with the zero of Greenwich were possible. The position of the observatory as finally determined and now offi-

cially of record is: Longitude, 71° 7′ 44.85,″ west; latitude, 42° 22′ 47.6″, north. As showing the error of the best attainable results by use of chronometers it may be remarked that by that method the central tower of the observatory was located at a point on the lawn half way between the front door of the director's dwelling-house and Garden street. The discrepancy is about 320 feet.

About the time of the first determina tion Commodore Owen of the British Navy was making an official survey of the coast of New Brunswick and Nova Scotia. Having confidence in what had been done at Cambridge he took that station for his zero in preparing his official report, ultimate reference being made to Greenwich. The first importation of chronometers appears to have been made jointly by Prof. Bond and Commodore Owen. When the report was submitted it was challenged by some of the British Board of Admiralty, who believed that the longitude of Halifax was better known. In due course Prof. Bond was inquired of, and his letter addressed to the board of admiralty, in explanation of the technicalities, proved convincing and its conclusions were cordially accepted, with thanks by Admiral Beaufort on behalf of the board. The officers-in-chief of the United States Coast Survey, and of the exploring expedition severally adopted the Cambridge meridian as the zero in preparing their official reports.

A new instrument purchased by the observatory, a 2$\frac{3}{4}$-inch equatorial, permitted accurate observations to be made of the solar eclipses of 1845 and 1846, the comets of the same years, the transit of Mercury in 1845 and of the newly discovered planet Neptune.

The 15-inch equatorial was set up on June 23 and 24, 1847. Certain nebulæ and the planet Saturn were the first subjects of study. Discoveries of importance were made in each field of investigation. The report of the visiting committee for 1848 notes the discovery by Prof. Bond on Sept. 19 of that year of the eighth satellite of Saturn, and speaks of it as "the only addition to the solar system ever made on the continent of America."

The few years immediately following the date of the great telescope may be called the romantic period in the history of the observatory. There was no instrument on this continent to be compared to it, and it had but one equal in Europe.

While the director of the observatory kept cool enough to utilize it to the utmost, he manifestly shared in the enthusiasm. One of the earliest to inquire what could be seen by it was Edward Everett, president of the college from 1846. Prof. Bond responded by letter on July 26, 1847, named several matters and ended by saying: "But I must recollect that you require of me only a brief account of our telescope. The objects revealed to us by this excellent instrument are so numerous and interesting that it is difficult to know where to stop." On Sept. 22 following Prof. Bond wrote to the president: "You will rejoice with me that the great nebula in Orion has yielded to the powers of our incomparable telescope."

He explains the reason for his rejoicing by saying that this nebula and that of Andromeda had hitherto been the strongholds of the "nebular theory," or the theory that the nebulæ are masses of matter in process of condensation into systems.

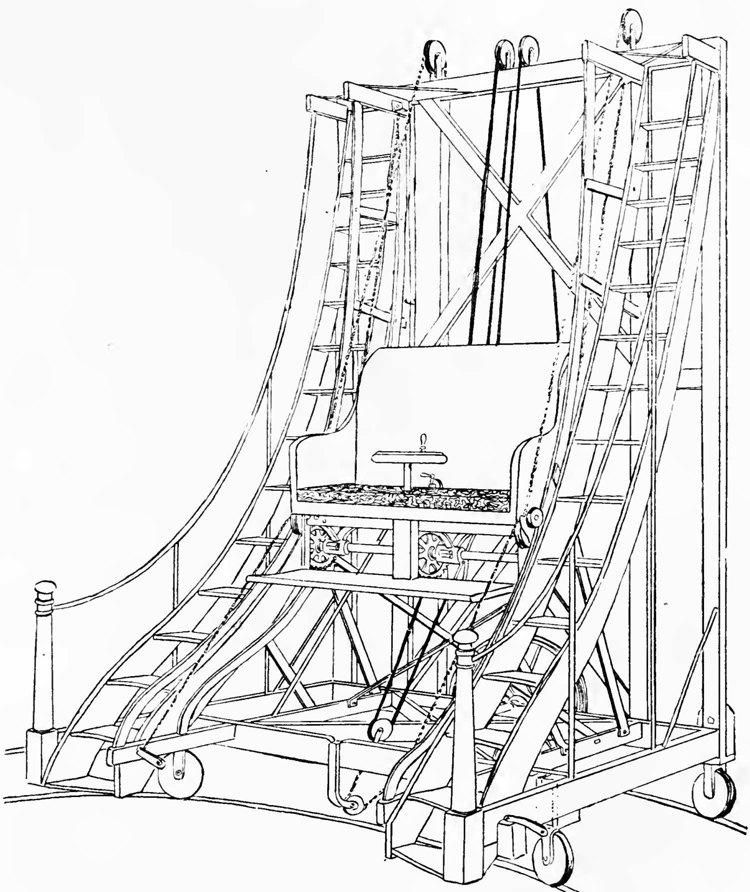
Now, the mass in Orion which, he said, had defied the telescopes of both the Herschels, and, at first, that of Lord Rosse, had been resolved into innumerable distinct points of light, or separate stars, by the Cambridge refractor, whose only competitor in the search was Lord Rosse's instrument, "the largest reflector in the world."

The phrase "incomparable telescope" was warranted. Nor does the didactic suggestion of the proverb about the new broom apply; for more than 30 years afterwards the present director of the observatory had occasion to say: "In 1877 besides the photometric measures of the satellites of Mars, a series of measures for their positions was also made. The number of these observations was second only to that obtained with the great telescope at Washington." Of the work done two years later, he says: "Of the satellites of Mars 1348 measurements were made, Deimos being last seen at this observatory as it gradually receded from the earth. This is remarkable, as our telescope has entered into competition with the largest telescopes of the world, some of which admitted two or three times as much light."

On Nov. 7, 1848, a transit circle was set up and it completed the set of new instruments at first proposed for the ob-

servatory. Previous to this date two new "comet seekers" had been received, the gifts respectively of President Quincy and Mr. J. I. Bowditch. With these in the six years beginning with 1845 the original discovery of ten comets was made by Mr. G. P. Bond. In his report for 1846 Prof. Bond says that during that year stellar and lunar observations had been made in co-operation with like work done by observers of the United States Coast Survey at West Point, Philadelphia and Nantucket, to determine longitudes for the purposes of the coast survey.

But visions of the sky were not the only matters of interest at the observatory in this early period. The great telescope was poised at a height of 13 feet from the floor of the dome, and its sweep was from three degrees beyond the zenith to as many below the horizon. The visual end of the instrument therefore might need to be set at any point along an arc of 90 degrees, and an observer would have to be something of an acrobat in successfully using it unless a suitable chair could be obtained. There was none in the world that filled all the requirements, and Prof. Bond invented and made one. It is in use, unchanged, to this day, and by means of its ingeniously combined wheels, cogs and pulleys the



W. C. BOND'S OBSERVATORY CHAIR.

observer can quickly and easily place himself anywhere along the vertical quarter circle and horizontal full circle traversed by the eye-piece of the telescope.

Prior to 1845 a transfer of 12 chronometers to and from Greenwich, Eng., had been made by Prof. Bond and Commodore Owen, for the determination of the longitude of the observatory. Other chronometer expeditions were conducted subsequently in co-operation with the United States Coast Survey, the final one being in 1855. In the summing up of results, 723 independent chronometer records were used. The magnitude of this undertaking, as a whole, surpassed anything ever attempted in any other country.

In his report, reviewing the year 1848, the director says; "Some experiments made with the daguerreotype and talbotype processes for obtaining impressions of the sun's image formed by the telescope have not been attended with complete success; however, we do not despair of ultimate success."

In the report for 1850 he is able to say: "With the assistance of Mr. J. A. Whipple, daguerreotypist, we have obtained several impressions of the star Vega. We have reason to believe this to be the first successful experiment ever made either in this country or abroad. From the facility with which these were executed with the aid of the great equatorial, we were encouraged to hope for further progress." In the report of the following year he speaks of pictures of the moon and stars obtained by this process, and adds with reference to his son's official visit to Europe that year: "Some of these daguerreotypes taken by the aid of our great object glass excited the admiration of eminent men in Europe. to whom Mr. G. P. Bond gave specimens." In an official letter he says of his son's visit to Paris: "He attended in May a meeting of the French Academy, and there presented a daguerreotype of the moon taken with our large telescope." Other specimens were placed in the great exhibition of London, or World's fair, of that year, and a council medal was awarded for them.

This tour in Europe by the younger Mr. Bond makes an interesting episode in the general record. He was everywhere cordially received by men of science, a fact attributable in part, no doubt, to his own reputation, but more especially to his being the representative of the new observatory, already of fame, established in the distant West.

On arriving at Cronstadt he was surprised at meeting an officer of the Russian government who had instructions to conduct him to the imperial observatory at Pulkova, where, during his stay in Russia, he was made the guest of the director of the observatory and given all possible attentions and facilities, including the "great privilege" of practically manipulating the instruments. Among these was the great telescope, the rival of the Harvard equatorial. During the tour he visited Sweden and saw a total eclipse of the sun. Among those from whom he had friendly receptions were Baron Humboldt, Sir John Herschel, Sir David Brewster, Sir G. B. Airy, Le Verrier, Biot Argelander, Gauss and Hansen; also Lord Rosse, whose great telescope he had opportunity to use.

In July, 1848, the wires of the magnetic telegraph were connected with the observatory at the expense of the coast survey, for determining by instant communication the longitude of certain principal cities in the United States. There are suggestions of both the modern and the antique world in the statement that in this first experience the electrical apparatus of a department of the institution founded by John Harvard, was connected with like apparatus in an observatory in the garden of Peter Stuyvesant in New York city. These electrical experiments of the coast survey were begun as early as 1844, between Washington and Baltimore.

Various improvements of method had been made, and that most approved was followed on this first occasion at Cambridge. The coast survey officer in charge had for his assistants Prof. Bond at Cambridge and Prof. Loomis in New York. An official letter of the electrician of the Coast Survey Department says: "During these experiments Prof. Bond conceived the idea of using an automatic circuit-interrupter."

Some question of priority as to this suggestion arose in later years. It was doubtless a spontaneous and original thought with Prof. Bond. though the suggestion appears to have been made earlier elsewhere, but it had not been acted upon "from apprehension of injury to the performance of an astronomical clock which must be used for the purpose." Experience

proved eventually the apprehension to have been groundless; but Prof. Bond's suggestion avoided any liability of the kind by proposing that an astronomical clock be made for the purpose.

In August, 1848, he received authority to have such a clock made at the expense of the coast survey. Reverting to the matter in a subsequent annual report, Prof. Bond says: "I caused such a clock to be made, and it is found to answer perfectly the intended purpose. But another and far more serious difficulty presented itself in the accurate registry of the beats of the clock after being transmitted by the galvanic circuit; and it was at this point that further progress

DAVID SEARS,
The First Donor to the Observatory.

in the application of this method to astronomical observing was arrested."

Experimenters were busy at Philadelphia, Cincinnati, and elsewhere, during the two years' interval in attempts to solve this concomitant problem, and with very considerable success. That none of these devices quite filled the requirements is manifest by the fact that they did not go into general use. But the perfected apparatus submitted to the officer of the coast survey by Prof. Bond, April 12, 1850, did go into such use. This instrument Prof. Bond stated to be the joint invention of himself and his two sons, George P. and Richard F. Bond. It was named at first from one of its peculiar parts, the "spring-governor," but the more comprehensive title of "chronograph" was later applied to it.

While as a piece of mechanism, it was distinct from the "circuit interrupter," the two were used conjointly, and thus acting in combination their operation in recording became known soon afterwards in England as "the American method." By this method the errors suggested by the term "personal equation" are greatly diminished, and a definiteness of record is attained, which permits the recording sheet to be read by the eye to tenths and by scale and lens to hundredths of a second. The successive sheets are the primary official record, and being bound into volumes, become a part of the permanent archives.

The apparatus was at once put to use in the several telegraphic stations of the coast survey; and one of the circumstances which made Mr. G. P. Bond's tour in Europe a notable one was its exhibition for the first time there. It was shown in operation and explained in a lecture by him before the Royal Astronomical Society, and also at the annual meeting of the British Association for the Advancement of Science. Through the urgency of Sir David Brewster and others it was set up in the great exhibition at London in 1851, where a medal was awarded for it. It had the highest award of the Massachusetts Mechanic Association, a gold medal. It was adopted at the Greenwich observatory soon after Mr. Bond's exhibition of his model, and speedily throughout Europe.

Soon after the electrical experiments of 1848 at the observatory the wire was put into use to transmit to Boston and different railway points, signals giving the true local time, these signals being electrically responsive to the movement of an astronomical clock in the observatory, the method of transmission being that of the "circuit interrupter." This system was at once adopted in England, wire connections being made with a clock in Greenwich Observatory. This time service of the Harvard Observatory, though continued during the intermediate period, was not organized as at present until 1872.

In 1852 the officers of Harvard Observatory co-operated with Captain Charles Wilkes in experiments for ascertaining the velocity of sound under different atmospheric conditions. In these tests cannon were fired near the observatory, at the arsenal in Watertown, at the navy

yard in Charlestown and at Fort Independence in the harbor, the central observing point being the cupola of the State House in Boston, where Captain Wilkes took his station. These experiments had immediate reference to a reduction into proper form of data obtained by the exploring expedition, wherein Captain Wilkes had caused surveys of islands and groups in remote seas to be made by sound. In these surveys, distances between points whence angles were projected were determined by the firing of cannon at those points.

In 1855 an endowment of $10,000 was made by ex-President Quincy as a memorial of his father, Josiah Quincy, a patriot of the revolution. This fund was specifically applied to the publication of annals of the observatory. The first volume was issued in 1856 and comprised a review of the work of the preceding years, so that the series of which it is the initial number makes a continuous record from the beginning. The series now numbers nearly 25 volumes. The decease of Prof. W. C. Bond occurred Jan. 29, 1859.

IV.

George Phillips Bond was the second director of Harvard College observatory, being the successor of his father, Prof. W. C. Bond. The date of his appointment was 1859. He was born in Dorchester, Mass., May 20, 1825, and graduated at Harvard in 1845. Thenceforth until his decease Feb. 17, 1865, he was in the constant service of the observatory. Prior to his taking the chief office his labors as assistant had gained for him a professional reputation; he had shared with his father the heavy task of organizing the observatory and carrying it on with slender means; he was familiar with its routine, and both by academical and practical training was peculiarly qualified for the position.

His professional record therefore is not to be limited to his own term as director. The computations required in the preparation of the three early volumes of the annals were to a great extent his work, and those pertaining to the chronometric expeditions between Boston and Liverpool, were wholly by him. He was the discoverer of the dark interior ring of Saturn, one of the first revelations of the great telescope, and discoverer also, as already stated, of ten comets within a brief period of years. In this cometary work it was his practice to sweep the whole visible heavens once every month.

His observations of Saturn led to the adoption of a new theory as to the constitution of the rings. During his term systematic observations were made of certain nebulæ, particularly that in Orion. He conducted a series of zone observations of faint stars near the equator, prepared a plan of observation and reduction, and with his own hand graduated the mica scales used in the work.

In 1860 he made an investigation of the brightness of certain celestial objects, including the moon and the planets, the results of which have a special value but are not identified with the Harvard photometrical series of later years, which relates to fixed stars only. During his term the formation of a star catalogue was begun, the observations being made with the meridian circle and in right ascension only, and much progress was made in picturing celestial objects by the camera, the process having, with the disuse of Daguerre's particular method, gained the generic name of photography.

The prestige of the beginning and early successes of astronomical photography attaches to the administration of the senior Bond; but his son shared fully in the labors of thought, contrivance and manipulation by which the original experiments were conducted, and in appreciation of the future possibilities to science in this new method of observation.

One evidence of this appears in a paper read by the younger Mr. Bond before the American Academy on May 12, 1857, the immediate occasion for its presentation being a most significant discovery made at the observatory a few days earlier.

The paper says: "Daguerreotype images of the star Vega were obtained at the observatory of Harvard College on July 17, 1850, and subsequently impressions were taken from the double star Castor, exhibiting an elongated disc, but no separation of its two components."

"These were the first, and until very recently, the only known instances of the application of photography to the delineation of fixed stars. A serious difficulty was interposed to further progress by the want of suitable apparatus for

communicating uniform sidereal motion to the telescope.

"This has been supplied by replacing the original clock of the great equatorial of the observatory by a new one, operating on the principle of the spring governor. Immediately upon its completion, a new series of experiments was commenced. These have been successful in transferring to the plate by the collodian process, images of fixed stars to the fifth magnitude, inclusive, with singular and unexpected precision. The most remarkable instances of success are the simultaneous impressions of the group of stars composed of Mizar of the second magnitude, its companion of the fourth and Alcor of the fifth magnitude. The following measurements of the angular distance of the companion from Mizar were taken from the plates."

A tabulated statement follows in the paper, giving dates from April 27 to May 8, with measurements from 13 photographic negatives produced on the respective dates. The mean for distance is 14.49 seconds, and for angle of position, 147°.80. For the same stars observed in the usual way, Struve's mean of six observations is, for distance, 14.40 seconds; for positions, 147°.40.

Mr. Bond's comments are: "The photographic method has thus in its first efforts attained the limit of accuracy, beyond which it is not expected the other can ever be sensibly advanced.

THE GOLD MEDAL; REVERSE SHOWING SIR WILLIAM HERSCHEL'S 40-FOOT TELESCOPE.

"Should photographic impressions be obtained from stars between the sixth and eleventh magnitudes as has already been done for those between the first and fifth, the extension given to our present means of observation would be an advance in the science of stellar astronomy of which it would scarcely be possible to exaggerate the importance."

Mr. Bond made important contributions to the literature of the science both in its mathematical and practical departments. Among the more notable of the former was a paper on cometary calculations and the method of mechanical quadratures, valuable in various respects, and notable in having anticipated an important improvement afterward given independently by Encke; also a paper on the use of equivalent factors in the method of least squares. He wrote a monograph covering observations of Donati's comet of 1858, for which he was awarded the gold medal of the Royal Astronomical Society and was the first of his countrymen to obtain that distinction. He began a paper on the nebula in Orion, which he did not live to complete, though during his prolonged last illness he continued his labors upon it, and dictated to an amanuensis long after strength to write had gone from him.

This paper was afterwards finished by Prof. T. H. Safford, then of Harvard, now of Williams College observatory. A biographer says of Mr. Bond: "Science to him was not a pastime but a serious calling, to be pursued with the utmost conscientiousness and singleness of pur-

pose. That he did so much and did it so well, during the few years allotted to him, must have been partly owing to an

PRESIDENT JOSIAH QUINCY.

extreme reluctance to dissipate his powers by beginning new works while the old were still unfinished." He received the honorary degree of A. M. from Harvard in 1853.

V.

Joseph Winlock was the third director of Harvard College observatory, being appointed in 1866. He was born in Shelby county, Ky., Feb. 6, 1826; he graduated at Shelby College in 1845, and was professor of mathematics and astronomy there until 1852. He was subsequently in the service of the Naval Observatory at Washington, and, still later, instructor in mathematics at the Naval Academy at Annapolis. At different dates, he was superintendent of the work of preparation of the Nautical Almanac. He continued in office as director of the observatory until his decease, June 11, 1875.

His administration appears by the record to have been one of various activity. A large amount of improved apparatus was added to the resources of the observatory, partly by purchase and partly by invention and making on the spot. He kept up the reputation of the observatory, which has never failed from the start, for originality and ingenuity in mechanical devices. It was during his term that the transmission by electricity of the true solar time to railroad centres and business points in all parts of New England became a regular part of the observatory work, and, by the system which he organized, compensation was made by corporations and individuals whose clocks were put into electrical connection with that at the observatory.

A considerable revenue has thus annually been derived. Other electrical apparatus of the observatory was modified and improved. A "switch-board," the device of his predecessor was much elaborated in its mechanism, whereby the electrical current was made more available and all the principal instruments were connected at will with the chronographs.

In 1868 when he visited Europe he procured the apparatus of a meridian circle of the latest device, the lenses being made in Cambridge. In setting up the instrument he saw opportunity to introduce various improvements in mechanism.

These were approved by experience and went into general use elsewhere. Another of his devices was "for the determination of absolute personal equation by mechanical means." Other contrivances, either wholly original or ingenious modifications of known apparatus, were an attachment to the spectroscope for automatic recording, being a modification of the chronograph: a combination of a stationary plane mirror with a fixed lens of great focal length — from 30 to 40 feet — for photographing the sun; a later improvement of this, by which the telescope was reduced to a single fixed lens of long focus and small aperture, chromatic aberration was avoided and the image on the plate could be made as large as was convenient for measuring; and a change of method by which the sun's image could be taken at the principal focus of the object glass and not beyond an eye-piece used to enlarge the image.

In February, 1866, when he took charge of the observatory, the great equatorial was applied to a series of observations of

double, and especially binary stars. This investigation was continued as steadily as circumstances would permit till 1872, and the results appear in the annals. In 1867 the first spectroscope owned by the observatory was imported, and in 1869 another. Two small direct-vision spectroscopes were also procured during Prof. Winlock's term.

In 1870 the new meridian circle, a superior instrument, was set up, and on Nov. 10 of that year was begun the series of observations for position of stars in the "Cambridge zone," so called, or that between 50° north and 55° north and overlapping 10′ upon each contiguous zone. The standard in using this instrument was an artificial star produced by lamplight.

During this term two expeditions were made with apparatus for observing total eclipses of the sun, and in both satisfactory results were obtained. On the first occasion, of date Aug. 7, 1869, the station was at Shelbyville, Ky., and on the second, of date Dec. 22, 1870, at Jerez de la Frontera, in Spain. In 1867 daily observations in terrestrial magnetism were made at the observatory for the purposes of the coast survey. In March, 1869, experiments for determination of longitudes were conducted on a continental

HARVARD OBSERVATORY STATION IN SPAIN.

scale, wire connection by relays being made with San Francisco. In these experiments apparatus which had been modified by Prof. Winlock was used and by this method, and also by another which was applied, it proved that the time of passage of a signal from Cambridge to San Francisco through the wire and six relays was very nearly three-quarters of a second. Between Dec. 13, 1869, and the summer of 1872, electric signals were sent by the Atlantic cable to and from Brest in France, via Duxbury, Mass. This survey was a joint enterprise conducted by certain of the great observatories of the world, that of Harvard being one of the two in this country having a share in the work. On July 4, 1870, was begun a series of photographs of the sun, and the work was continued nearly or quite to the end of Prof. Winlock's term, many hundred photographs being comprised in the list.

In September, 1871, was begun an elaborate investigation of lunar phenomena, which continued a year. In 1871 an arrangement was made with the coast survey by which a series of photometric observations was carried through, and for this a Zöllner astro-photometer was imported. The work was continued three years, though not all of it at Cambridge. The results are in the annals in 1878.

The purpose of these tests was to establish with precision the difference of longitude between America and Europe. Prof. Winlock supervised the work of preparing and engraving a series of plates illustrating remarkable celestial

objects. These gave special value to the volume of annals in which they appeared, causing an unprecedented demand for copies, so that it is now a rare book. His publications were not numerous, but there is no doubt that his scholarship, versatility and wide experience would have yielded valuable additions to the literature of science had his life been prolonged.

The means at command during his term did not warrant the publication of many volumes of annals. Though for nearly 10 years in office he did not live to

PROF. JOSEPH WINLOCK.

see any of his own observations published or even to complete the work of his predecessors.

During the term the permanent funds of the observatory were increased by the bequest of James Hayward $20,000, and that of James Savage $20,000. In 1870 a subscription of $12,450 was completed for purchase of a new meridian circle. In the preceding term a gift of $10,000 was made by William Sturgis for the publication fund. Prof. Winlock had the honorary degree of A.M. from Harvard in 1868.

VI.

Edward Charles Pickering, the present director of the observatory, was appointed in 1876. He was born in Boston and is of the Essex family of the name, Colonel Timothy Pickering being his great-grandfather. He is a graduate of the Lawrence Scientific School of the class of 1865. During the next two years he was a teacher of mathematics in that department of Harvard University. Later and up to the time of his appointment as director, he was professor of physics at the Massachusetts Institute of Technology.

A system of teaching physics called the "laboratory method" was introduced by him there, and his text-book illustrative of the method has to a great extent been adopted by like institutes. Astronomy, as a department of physics, came into the general course, and the attention necessarily given, for the purposes of instruction in the institute, to the technics of that subject, and to demonstration, served as preparation and discipline for the official responsibilities which he afterwards assumed.

He was a member of the Nautical Almanac party for observing in Iowa the total solar eclipse of 1869, and was in like service in the following year as a member of the United States Coast Survey party which observed in Spain a recurrence of that event.

When he came to the directorship he found the observatory to be well equipped as to instruments and its small working force efficiently employed. Their number was but five or six, which was all the means of the institution permitted of.

Like pecuniary restrictions continued until 1879, when a subscription was completed providing for the institution, $5000 annually for five years. Since then much larger gifts have been bestowed and the instrumental equipment, in recent years especially, has been whatever the latest demands or suggestions of science called for; the observatory staff has been augmented from time to time, till it now numbers about 40 persons, and the field of observation has been extended to include the southern hemisphere of stars.

Upon the premises at Cambridge where in 1876 stood only the main observatory and a lesser adjunct structure are now eight or ten others, a cluster of small wooden buildings, domed or otherwise adapted for astronomical uses, each containing a costly instrument of the most approved device; and besides these a dwelling house has been transformed into a hall, or rather a workshop of photography, and makes the northernmost structure of the little city of science

which has been set upon Summer House hill.

Upon Mt. Wilson, in California, in north latitude, and Mt. Harvard, in Peru, in south latitude, stand other unpretentious buildings, from within which observers of the Harvard corps nightly search through the translucent upper atmosphere of those regions to the respective poles. This aggregation of means has yielded ample returns; to say which is to signify that during the period under consideration the institution has made a noteworthy record, and that its affairs have been guided with befitting skill and judgment.

The total permanent funds at the beginning of the present term amounted to about $170,000. The subscription for five years was intended for immediate expenditure. At the end of that period a permanent fund of $50,000 was obtained in like manner. In 1885 was added to the permanent funds the bequest of Robert Treat Paine of his whole estate, of which $164,198 became at once available. In 1886 was made the first of a series of annual gifts of large sums of money by Mrs. Anna P. Draper of New York as a memorial of her husband, the late Prof. Henry Draper. These gifts have constantly been applied in furtherance of photographical observation, especially in that line of investigation which Dr. Draper himself began in his lifetime. In 1887 the bequest of Uriah A. Boyden, amounting to $238,000, became available. This bequest has conditions providing for astronomical work at considerable elevations as free as possible from disturbing or obstructing conditions of atmosphere. The income of the Paine fund may be applied generally.

In pursuing the inquiries thus suggested, and others, the observatory has adhered to its traditions, wherein original investigation has been directed to the physical rather than the mathematical side of astronomical science.

In his first annual report the present director outlined the immediate policy, in the then restricted state of the finances, to be to keep employed chiefly the two most costly and effective instruments, the great equatorial and the meridian circle. The latter was already in constant use in the work of the Cambridge zone.

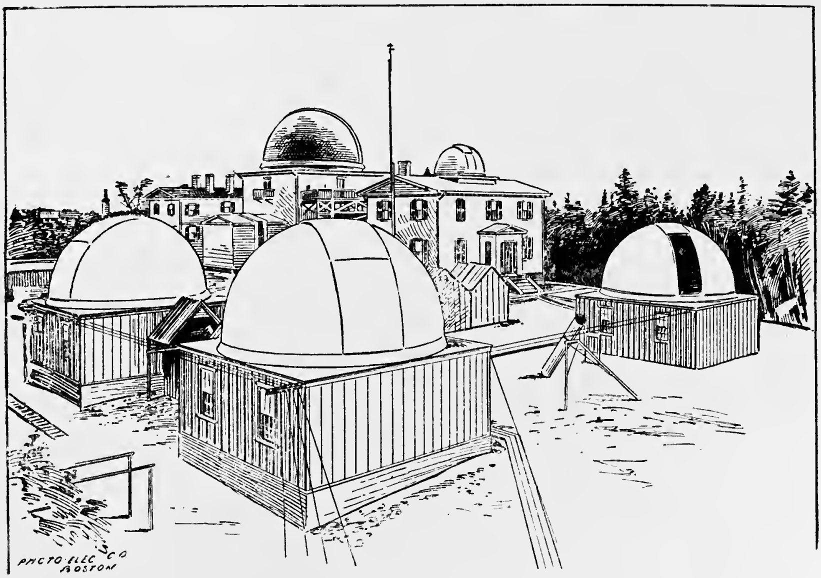
With reference to the former, the report having named the several specialties which the great observatories of this country had taken, each to itself, said: "Photometry offers a field almost wholly unexplored with large telescopes either in this country or abroad. It has therefore been selected as that to which the greater portion of the time of our telescope will be devoted."

The investigation thus entered upon, together with the zone observations just mentioned, and the continuation by ampler and in some particulars radically different methods of investigations in spectroscopy and photography, have given the institution a wide renown. But hardly less conspicuous are certain other achievements in the long list which makes the complete record. Without attempting to give any of these rank, still less to repeat the list, a few may here be mentioned upon the ground of their presumed popular interest.

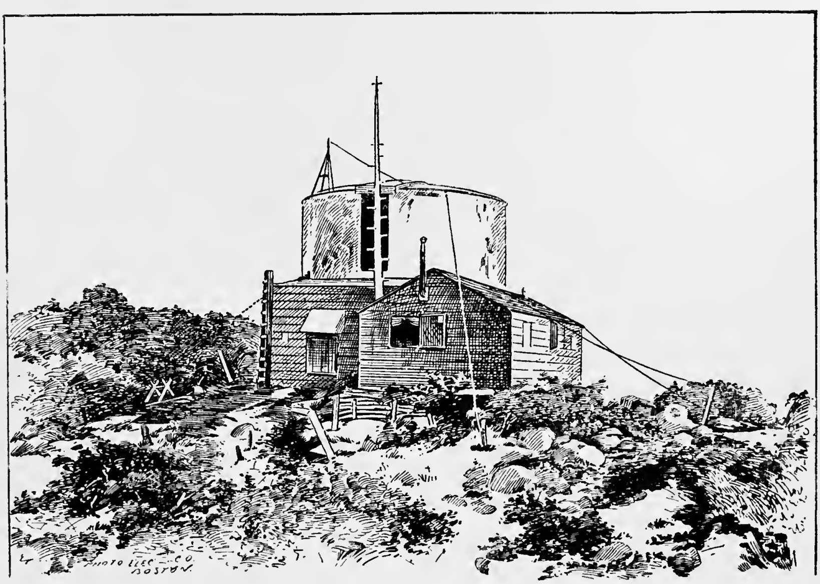
In 1878 the utility of the time signal service was increased by causing a time ball to be dropped every day at exact noon from a conspicuous point in Boston within view of the shipping of the harbor. The time was that of the meridian of the State House in Boston. When the standard or 75th meridian time went into general use the practice was conformed thereto. Indeed, the terms of the proposition might be reversed so as to indicate that, in the final determination, the responsibility was put upon the observatory to lead off in the matter.

There had been some discussion in the public prints and elsewhere of the advisability of adopting a common meridian time for large areas. In the report of the observatory for 1878 the theoretical presentation of the case which had been made by those advocating the change was sanctioned, and the new time was recommended as sure to be of public convenience if generally accepted. General consent was somewhat slow in its manifestation, but eventually the managers of all the principal railroads of New England agreed to adopt the plan if the time-signalling system of the observatory should be made to correspond in respect to clock connections, time ball, etc.

This was instantly agreed to, and with due prior public notice the new time went into use Nov. 18, 1883, and the Boston noon ball was first dropped on that day at exactly five hours later than the noon of Greenwich.



HARVARD COLLEGE OBSERVATORY.



HARVARD STATION IN CALIFORNIA.

In 1880 the full routine of meteorological observation was abandoned, as several institutions were doing like work. The record of the observatory in meteorology, which had continuously been kept up for 40 years, was reduced to proper form for printing, and was published in 1889. Certain observations of this kind have, however, been continued in the record to the present date.

In 1888 a plan of co-operation was agreed upon with the N. E. Meteorological Society and Mr. A. L. Rotch of the Blue Hill, Mass., Observatory, by which their results, which are of a comprehensive character, have since been published in the annals of the Harvard Observatory.

In 1877, in co-operation with Miss Mitchell of Vassar College Observatory and her assistants, observations were made at Cambridge for determining the longitude of the Vassar Observatory. Between Feb. 15, 1879, and Jan. 3, 1880, like observations were made in co-operation with officers of the Winchester Observatory of Yale College to ascertain the longitude of that institution. Between June 2 and June 23, 1883, similar work was done to fix the longitude of McGill Observatory in Montreal.

In the summer of 1888 ten evenings were given for observations for the longitude of Smith College in Northampton. The observers were Miss Byrd, teacher of astronomy at that college, and Miss Whitney, professor of astronomy at Vassar College. Harvard's contribution in the affair consisted in providing facilities on the spot, including the use of a transit instrument. These are instances, which among others go to show that because of infinite painstaking at Harvard in the earlier years it has become the Mecca to which all on this continent who wish to be perfectly assured in the matter of longitude may prudently make a pilgrimage.

In 1881 an arrangement was entered into for prompt communication as to unusual celestial phenomena, discoveries, etc., among astronomers in this country and in Europe. A cipher code, the invention of Messrs. S. C. Chandler and John Ritchie, Jr., of the observatory staff, was put into use. It is known as the "Science Observer Code," and as it is superior in accuracy to former codes has been widely recognized. In 1883 Harvard observatory was made the official distributing centre for this class of news, by consent of the Smithsonian Institute, which had previously performed the service.

Upon the occasion of the transit of Mercury across the sun's disk in May, 1878, all the available telescopes of the observatory were put to use. The results, which included many photographs, were satisfactory, considering the unfavorable weather. During the like transit of Venus, on Dec. 6, 1882, six telescopes being in use, large additions were made to the important data which planetory events of this kind may supply.

In August, 1886, a small party provided with instruments belonging to the observatory made an expedition to Grennada, near the northern coast of South America, for observation of the total solar eclipse of that year. The expedition was in charge of Mr. W. H. Pickering, who afterwards became a member of the observatory corps.

On Jan. 1. 1889, a large party, under the same direction, observed a recurrence of the event in California. The observations were mainly photographical. Excellent results were obtained in both cases, though less in amount in the former, because of unfavorable weather.

Much has been done during the term in cometary investigation, but latterly comets have been observed, as a rule, only immediately upon discovery and towards the end of their visible period, or after they had got beyond the reach of any but the most powerful telescopes.

In the summer of 1883 the director journeyed in Europe and visited the principal observatories there. In the following annual report he names as an important result of his journey the obtaining of copies of unpublished manuscripts of Argelander and Sir William Herschel. The former are memoranda of observations of variable stars and the latter of observations made more than 100 years ago of the light of all stars of Flamsteed's catalogue.

The work on the Cambridge zone of stars was completed, as respects the primary plan of observation, on Jan. 26, 1879, and at that stage was regarded as one of the largest astronomical undertakings ever carried through in this country.

The reduction of the data was accomplished in 1883, but as was expected, a

necessity for reobservation appeared in certain cases. This work was done between Oct. 9, 1883 and Aug. 9, 1884. The observer from the beginning had been Prof. William A. Rogers. He resigned his position as assistant professor in the observatory in 1886, but continued to serve as editor of the published results. The whole series makes half a dozen or more volumes of the annals. The European supervisors of the general undertaking, well pleased, apparently, with the early instalments of manuscript returns, assigned to Harvard the work of reobservation of another zone, that between 9° 50′ south and 14° 10′ south. This work is still in progress. Each zone comprises about 8000 stars or nearly 17,000 in all.

The publications of the observatory during the present term in the form of annals, and as contributions by members of the corps to various journals of science, have been numerous and extensive. At the beginning of the term but four volumes of annals had been issued, though about an equal number were in some stage of progress in the printers' hands, publication having gone on slowly from lack of means. At the present time the continuous series of 22 volumes has been issued, excepting the second or supplementary parts in two or three instances. These parts are nearly ready, and the manuscript for about half a dozen more volumes in regular succession has, in part or whole, been given to the printer.

A review of what has been done during the present term in the departments of photometry, spectroscopy and photography will be comprised in the next and closing number of this series.

VII.

Agreeably to the announcement of the annual report of Harvard College Observatory for 1877, as to photometry, a beginning was made by constructing a photometer suitable to be attached to the great telescope. Other photometers have been devised at different times for use independently. One of the earliest was applied during the year beginning Oct. 12, 1877, in measuring the light of all known satellites excepting the two inner ones of Uranus, which are too faint to be discerned, even by the great telecope. The first prolonged observation entered upon was of the eclipses of of Jupiter's satellites.

As there are four satellites and as the plane of their orbits is nearly the same as that of the planet itself, eclipses are frequent. The plan proposed the observation of all these eclipses visible during a revolution of Jupiter around the sun, a period of about 12 years. The work was begun June 23, 1878, and has been regularly pursued. The final result will be of the highest value in that, among its utilities it will permit a new and independent computation to be made of the earth's distance from the sun, which distance is a prime factor in theoretical astronomy.

Computations hitherto made, based upon data derived from these eclipses, are not authoritative, because of disagreements among different observers using different telescopes, and because of defects in the method of observation.

The director's report for 1878 says: "Errors of this kind are much lessened by photometric observations of the satellites as they gradually enter or emerge from the shadow of Jupiter, using the planet itself or another satellite as a standard. Each comparison thus obtained gives an independent determination of the time of the eclipse, free from the errors due to the condition of the air or the power of the telescope employed and less likely to be affected by personal equation than the observation of a disappearance or a reappearance. By the ordinary method an observation during twilight can have little value, while good photometric observations may be made as well then as at any other time. It is even possible to make them before sunset."

In 1879 a work of magnitude was begun—the photometric observation of all stars down to those of the sixth magnitude visible in this latitude. For greater facility, and particularly to avoid loss of time in identifying stars of small magnitude, it was decided to make a new departure in method and in construction of an instrument. The new instrument was called the meridian photometer, and stars were observed by it only when near the meridian. The position of any star being well known, the time of its appearance in the field of the telescope could be foreseen.

Each that was desired for a particular night had, therefore, only to be waited for, not sought for. The original instrument consisted of a fixed horizontal telescope pointed west and having two objectives.

The light of the pole star, which was taken for the standard or unit of measurement, was reflected by a prism into one object glass, and that of the star to be measured into the other. The light of the brighter star was then reduced to exactly that of the fainter by the turning of a screw having a register attached. The indication of the register gave the measure, which was confirmed by repeated observations. Telescopes mounted in the ordinary way continued to be used in other branches of photometric work.

The photometric survey of the sixth magnitude and brighter stars was completed Aug. 25, 1881. In 1882 a new and more powerful meridian instrument was constructed and a photometric survey of a list of about 21,000 stars, from the sixth to the ninth magnitude, was entered upon. This work was finished Sept. 29, 1888, and soon afterwards the instrument, with others, was sent to Peru in charge of Mr. S. I. Bailey of the observatory corps, where, May 11, 1889, a corresponding survey of the stars, from the first to the ninth magnitude, inclusive, between 30° south and the southern pole, was begun. Thus the facts relating to all the stars in the sky of these classifications will be embodied in the final result.

The record, which will comprise several volumes, one or more of which have already been published, will have an identity throughout as respects the method, the instrument, and the unit of measurement. It will be authoritative as a text book or series of text books, and will enhance the value for reference, and comparison of various records of the light of stars, both those of modern and ancient date.

HARVARD OBSERVING STATION AT WILLOWS, CAL., JANUARY 1, 1889.

The successful working of the two meridian photometers led to the construction of one still more powerful, having an aperture of 12 inches. The first was of $1\frac{1}{2}$ inch aperture, and the second of four inches.

The three differ somewhat in mechanism, but are the same in principle. The 12-inch is called by distinction the "horizontal telescope." It will be available in case a photometric survey of stars of fainter magnitudes shall be undertaken, but its use is not limited to photometry.

In 1879, a photometer was devised for measuring the light of nebulæ, thus applying to these objects and to stars the same unit and scale. In 1881, photo-

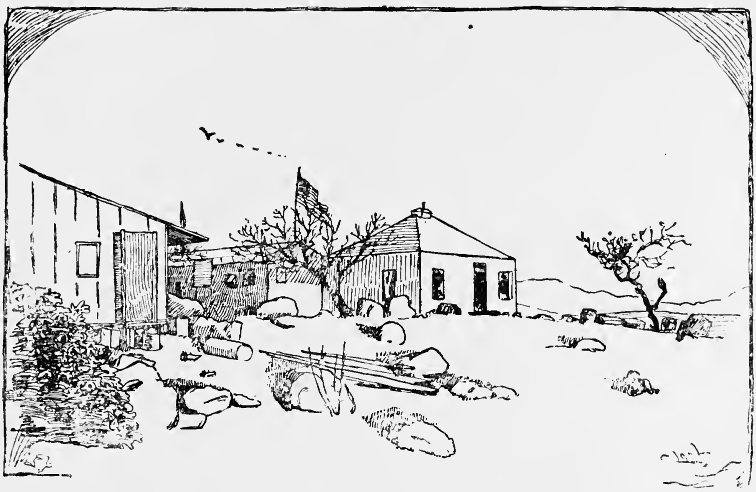
metric observations of certain bright parts of the moon, were made for the Selenographical Society of England, the particular parts being selected by that society. It thus was shown that the lunar scale of light in common use may be closely expressed in terms of stellar magnitude, each degree of the lunar scale answering to six-tenths of a magnitude. Photometry has been very extensively applied at Harvard in study of variable stars.

A history of any department of practical astronomy, written from the point of view of a mechanician, could hardly fail to be of interest. Among the curious experiences at Harvard in the line of photometry is one which illustrates this point, and, at the same time, indicates the refinements in observation which are resorted to, and demonstrates one of the utilities of the photometric method.

In 1877 announcement was made of the discovery at Washington of two satellites of the planet Mars. The Harvard telescope being applied they were after a little effort descried as two faint points of light, showing no visible disks. To ascertain the diameter of each satellite might therefore seem impossible: but it was done, approximately, by the photometric method.

The mechanical problem was to reduce the light of the planet as seen in the telescope to an equality with the light of one of the satellites as thus seen. Five or six different mechanics were employed to drill in a piece of metal a hole, making a true circle, and small enough to produce the equality sought for by sufficiently diminishing the light of the planet. It may be remarked that one of those who succeeded best had already, for his own purposes, managed to drill a hole, lengthwise, through a fine cambric needle, making a steel tube of it.

What he made for Prof. Pickering was a hole in a steel plate, the diameter of which was one eighteen hundredth (1-1800) of an inch. It was so nearly circular that the various diameters, including errors of measurement, only differed one one hundred thousandth (1-100,000) of an inch.



HARVARD OBSERVING STATION IN PERU.

Other mechanical devices were resorted to for corroboration, and the results reached were that the diameter of one of the satellites is about six miles, and that of the other about seven miles. They are the smallest known in the solar system.

The availability of the spectroscope in astronomy had early been appreciated by the profession. In experiments in this line it had been found that a classification of the nebulæ might be made upon the basis of their spectra. In 1880 the study was carried a stage further at Harvard in ascertaining by the spectroscope that certain faint objects, which,

by direct vision, had been judged to be stars, are in fact nebulæ. In 1881, it was found that the spectroscope is serviceable in the discovery of variable stars. Thus incited, a new instrument was imported from London, but it did not prove satisfactory.

Nothing of importance appears to have been done in this department thereafter until 1886, when the proposition of Mrs. Draper opened the way to investigation of spectra by aid of photography. For this the 11-inch photographic telescope, which had been used by Dr. Draper, was loaned by Mrs. Draper, who also met the expense of a new mounting and a special observatory building. A beginning was made with an eight-inch instrument, known as the Bache telescope. It is of the pattern described as the "doublet," and offers the advantage of a large field of view. With it the spectra of about 10,500 stars of the sixth magnitude and brighter, between the pole and 25° south, were photographed before the close of the year 1888.

The instrument was then sent to Peru, where a like survey of the Southern sky is in progress. Spectroscopic observations of the brighter stars have been continued at Cambridge with the 11-inch Draper telescope and of fainter stars with an 8-inch doublet similar to the Bache instrument. In this work it was found that by giving a certain chemical stain to the photographic plate the yellow and green portions of the spectrum of even the fainter stars can profitably be studied.

Furthermore, what seems incredible at first thought, it appears to be demonstrated that the components of binary stars whose juxtaposition does not permit them to be separated in any telescope, may, by spectroscopic photography, be shown to be in revolution about each other. Two or more such objects have been found in which the changes regularly succeeding in the lines of the spectrum not only prove that the components are in motion, but permit the period of revolution to be determined.

Prior to 1883 photography is mentioned in the annual reports of the present director only as incidental to other work. In that year a systematic investigation was undertaken, having among other objects in view, the construction of a photographic map of the whole heavens. An early application of photography in this investigation was in the direction of determining the color of stars, measuring their brightness by an independent method, picturing their spectra, exhibiting the effect of atmospheric absorption of light in a series of plates covering the period of a year, and ascertaining by images of stars trailed upon the plate, the clearness and steadiness of the atmosphere.

In 1887 the Boyden fund being available, the first step was taken in the important enterprise of giving a continental expansion to the work of the observatory. The aim of the testator in making his bequest could well be furthered in conducting observations simultaneously in photometry, spectroscopy and photography. In following up the project, the Draper memorial funds appear also to have been available to a considerable extent in the two latter methods of observation. Experimental stations were established in Colorado in the summer of 1887 on mountain peaks of 14,000, 11,000 and 6000 feet in height, respectively, and the meteorological conditions, including the transparency and steadiness of the upper atmosphere, were duly tested.

This investigation was continued at the expense of the Boyden fund during the following winter by local observers whose stations were at considerable height.

In 1889 the movement was further extended by establishing an observatory on a peak about 6500 feet high in Peru, 25 or 30 miles distant from the sea coast and the city of Lima. Local official sanction was given to naming the peak, "Monte Harvard." About the same time other observers of the Harvard corps set up an experimental observatory on Mt. Wilson, 6000 feet high, in Southern California. The station is about 30 miles from the sea coast and somewhat less from the city of Los Angeles.

The experimental purpose is the same as in Colorado, and looks to the ultimate establishment of a permanent observatory as a branch of the Harvard institution at some favorable point where the superior atmospheric conditions of the Pacific mountain regions can be had. In the special direction of picturing celestial objects at Mt. Wilson remarkable photographic results are already possessed at Cambridge in plates showing

lunar surfaces, Saturn's rings, Jupiter's belts and the most brilliant of the nebulæ. That among them which is of the greatest scientific interest, as being a novelty, is the picture on a negative plate of the great spiral nebula of Orion. It is a Harvard discovery by the photographic method, and is quite other than that heretofore known as the great nebula in Orion. That is an object having a span of about half a degree. The new great nebula has a span of nearly 17 degrees; its outline includes all the stars of the constellation, and it is too faint an object to be discerned by the naked eye.

It is one of the principal advantages of the photographic method in astronomical work that the sensitive plate will denote objects which the eye reinforced by a telescope of any power cannot detect. The great nebula thus discovered is within reach of the telescope, but its dimensions are so much larger than the field of the telescope, and its outline so faint, that its true character would not thus originally be apprehended.

Photography at Cambridge has already produced several series of plates, each plate covering a section of the northern sky, the whole of which when perfected and collated will be a self-recorded, and so, indisputable atlas, showing the position of all stars down to those of the 11th magnitude. It will be an atlas in sheets of glass, and frailer in some respects than if composed of sheets of paper. But for study of the science the glass is better than any product of the engraver's art, and better than any sun picture printed by the plate itself. Indeed, it is one of the triumphs of the photographic method that a perfect photographic negative discloses more to the student than does a telescopic view of that area of the sky of which the photograph is a copy. Astronomical research is now constantly made at the observatory in this manner, and with results equal to or better than those reached by former methods.

Celestial objects are thus originally discovered and the positions of familiar objects remeasured or otherwise compared, and this work might be continued throughout the whole 24 hours were it so desired, regardless of the glare of the sun by day or of impenetrable clouds by night.

The work in progress in Peru will give other series of plates offering equal facilities for the study at Cambridge of that part of the sky which is beyond our southern horizon. Some of the results which these extensive investigations of the light, the spectra and the positions of the stars will yield will anticipate the doings of other great observatories of the world. But there is no necessary limit at stars of the magnitudes named; there will remain other worlds to conquer

A special encouragement to new enterprises at Harvard is in the munificent gift of $50,000, made within the year past by Miss Catherine W. Bruce of New York for the construction of a telescope of 24 inches aperture, to be used in photography. A contract for this instrument has been made. It is intended that its first use shall be to photograph maps of the fainter stars, and it is hoped that those as faint as the 16th magnitude can thus be represented. The basis of this sanguine forecast is the fact that with an eight-inch telescope of the pattern of the proposed 24-inch, and an exposure of the plate for one hour, twice as many stars are photographed as are visible with a telescope of 15 inches aperture. Prof. Pickering received the honorary degree of A.M. from Harvard in 1880, and that of LL.D. from the University of California in 1886, and from the University of Michigan in 1887. Like his predecessor, Prof. G. P. Bond, he has been honored by the Royal Astronomical Society in the bestowal of its gold medal.

The several investigations of chief importance which are now in progress at Harvard College Observatory have already been mentioned as part of the record of the half-century past. They also go into the record with which the second half-century now begins. As such they may be briefly recapitulated, viz.: The survey, for the purposes of the great European standard catalogue known as the "Astronomische Gessellschaft," of the zone between 9° 50′ south and 14° 10′ south; the photometric, spectroscopic, and photographic special surveys making in south latitude to complete like surveys hitherto made at Cambridge, extending to about 30° south; the systematic work in photography, which includes much classifiable as spectroscopy, carried on both at Cambridge and in Peru as the Draper Memorial work; other systematic work of like importance done under the special restrictions of

the Boyden fund; and what perhaps may be called the orbital observations of eclipses of Jupiter's satellites.

That planet has now nearly completed its circuit around the sun, and the last of its satellite eclipses to be observed will occur on Dec. 17 ensuing. During the period of 12 years about 450 of these eclipses have been observed and recorded. Perhaps as many others for which preparations were made at the observatory, passed unseen, because of interposing clouds. Except to an expert these figures give no hint of the magnitude of the work. All that need here be said is that in its completed form it will be one of the great achievements of the observatory.

The enumeration of these unfinished works and those completed, which has now been made, will have fulfilled its purpose if it shall have impressed upon the mind of the general reader the fact, with which it is presumable everybody is somewhat familiar, that a great oak has grown from the little acorn planted on Harvard College campus 50 years ago.